
Observing Lightning and High-Energy Radiation from Thunderstorms

Birkeland Centre for Space Science, UiB
National Aeronautics and Space Administration (NASA), USA
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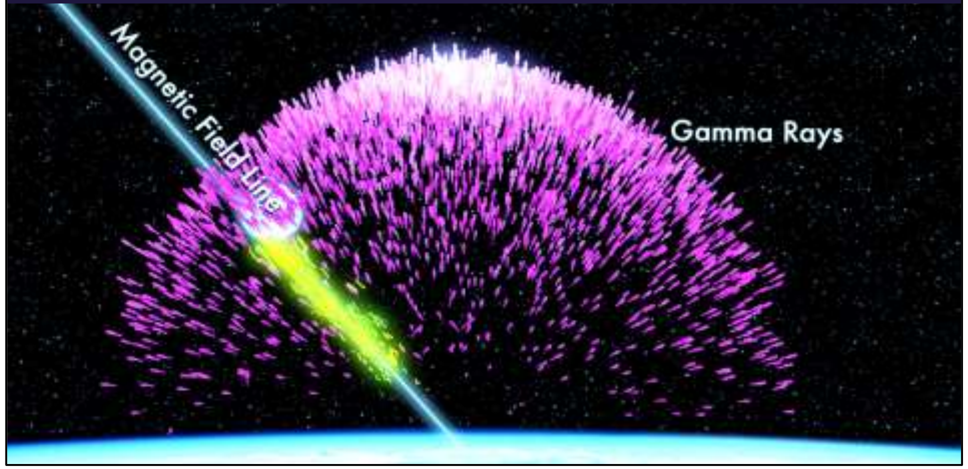
BIRKELAND CENTRE FOR SPACE SCIENCE




# FEGS Measurements During the 2023 ALOFT Campaign

*2023 GLM Science Meeting*

Mason G. Quick

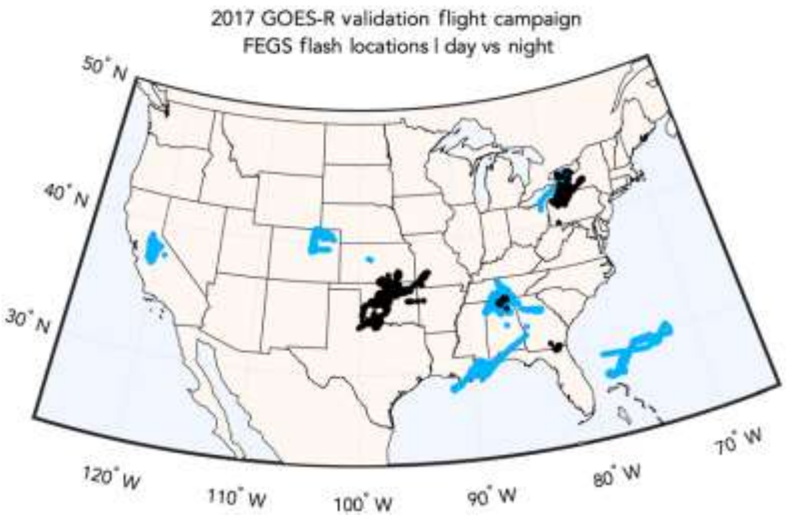
Nikolai Østgaard, Timothy Lang, Martino Marisaldi, Eric Grove, Christopher Schultz, Ian Adams, Rachael Kroodsma, Gerald Heymsfield, Hugh Christian, Randall Longenbaugh, Richard Blakeslee, Andrey Mezentsev, David Sarria, Phillip Bitzer, Morris Cohen, Steven Cummer, Martin Fullekrug, Joan Montanya, Marni Pazos, Mark Stanley, Camilo Velosa

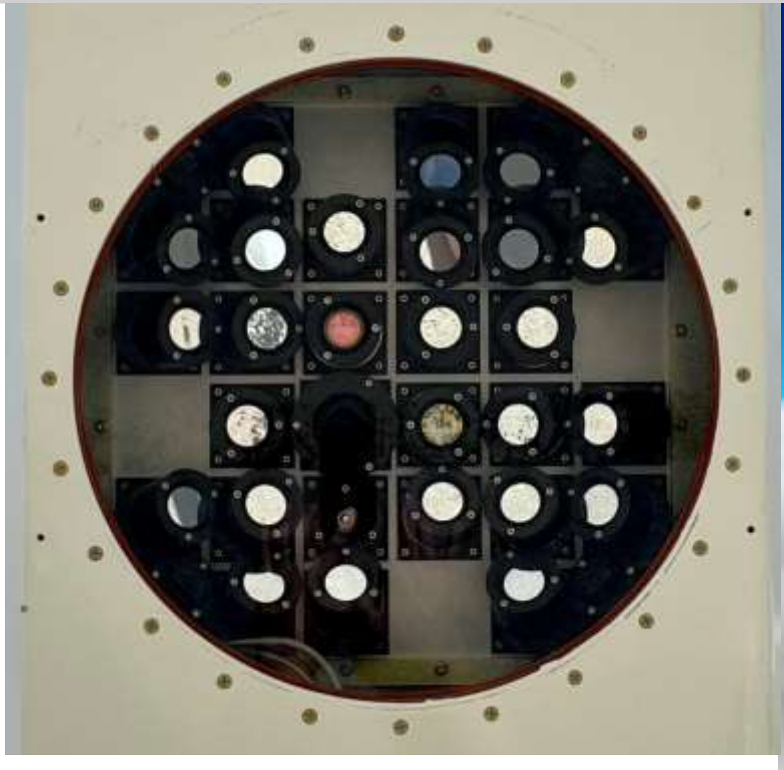
# Fly's Eye GLM Simulator

- Multiband radiometer array
- Main array 5 x 5 grid (780 nm)
- 5 alternate spectral bands (swappable)

- First flight in 2017 for GOES-R post launch validation

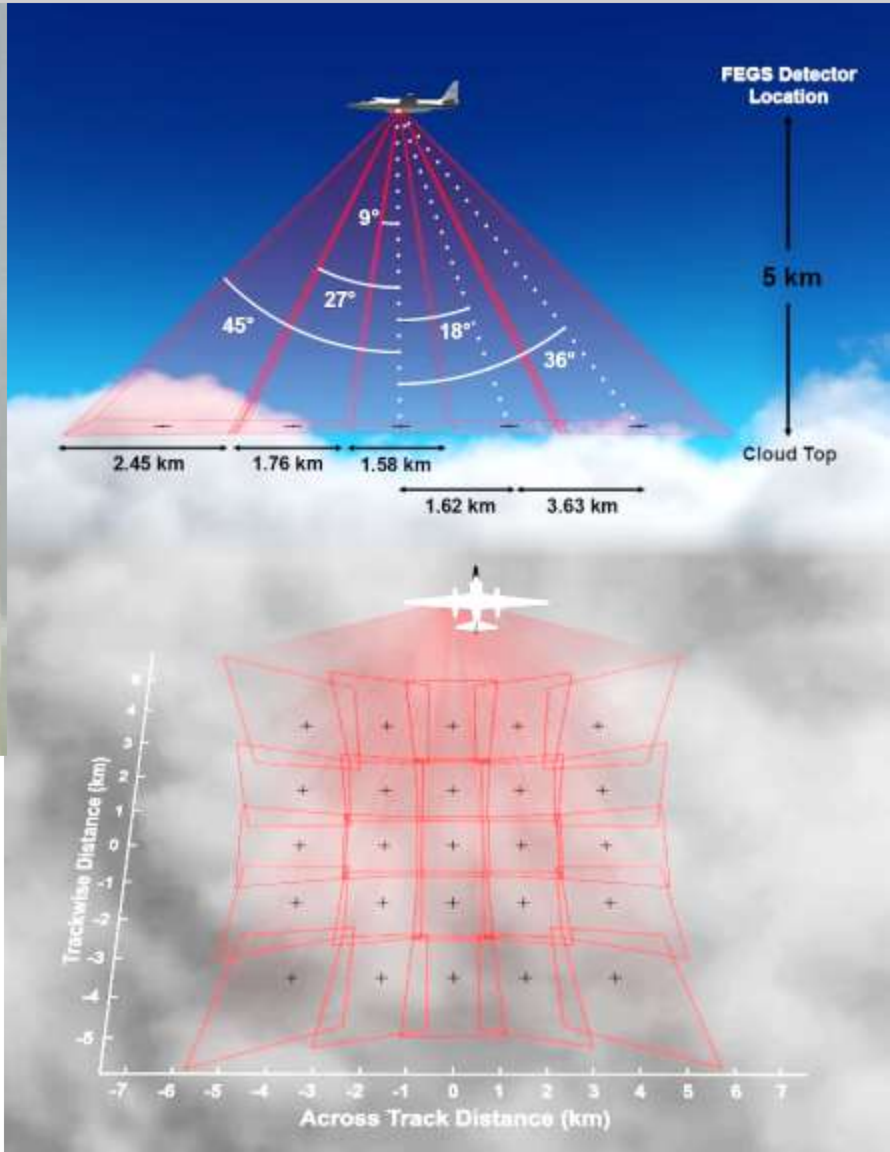
- Served primary mission to provide a ground validation dataset for Geostationary Lightning Mapper (GLM)



FEGS in 2023

Mason G. Quick, Hugh J. Christian, Katrina S. Virts, Richard J. Blakeslee, "Airborne radiometric validation of the geostationary lightning mapper using the Fly's Eye GLM Simulator," J. Appl. Rem. Sens. 14(4) 044518 (9 December 2020)
[https://doi.org/10.1117/1.JRS.14.044518](https://doi.org/10.1117/1.JRS.14.044518)



# Airborne Lightning Observatory for FEGS and TGFS (ALOFT)


4 instrument suite to measure lightning emission from radio frequency to gamma-ray emission

- FEGS – multiband radiometer array (UV to NIR)
- EFCM – electric field change meter. Two channel flat plate antennae to observe impulse dE/dt signatures produced by discharge processes

*Two High Energy Scintillator Packages*

- iSTORM - In-Situ Thunderstorm Observatory for Radiation Monitoring
- UiB-BGO – Bismuth Germanium Oxide package built by University in Bergen.

# ALOFT campaign July 2023

ALOFT campaign was an outstanding success!

Talks at AGU 2023!

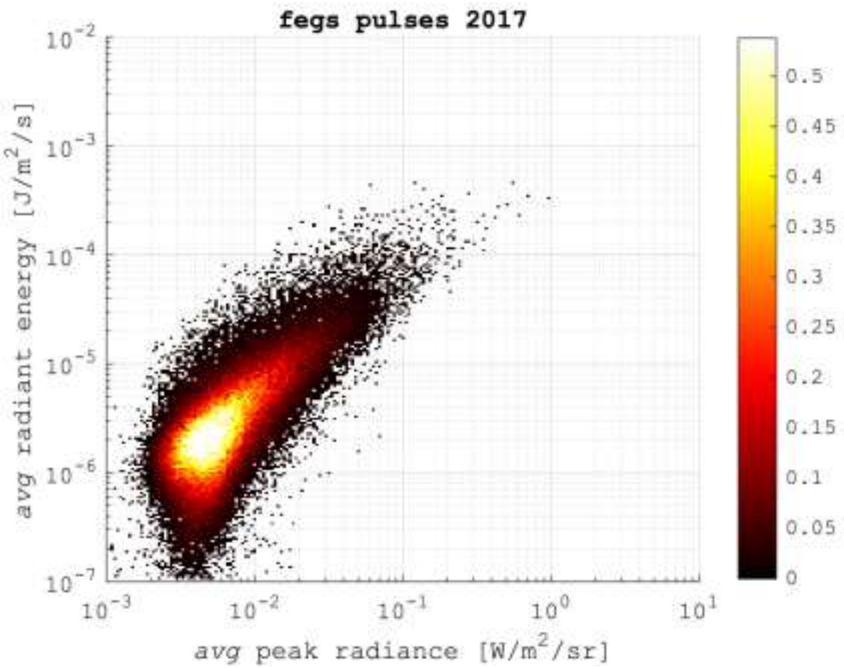
Over 100 TGFs observed

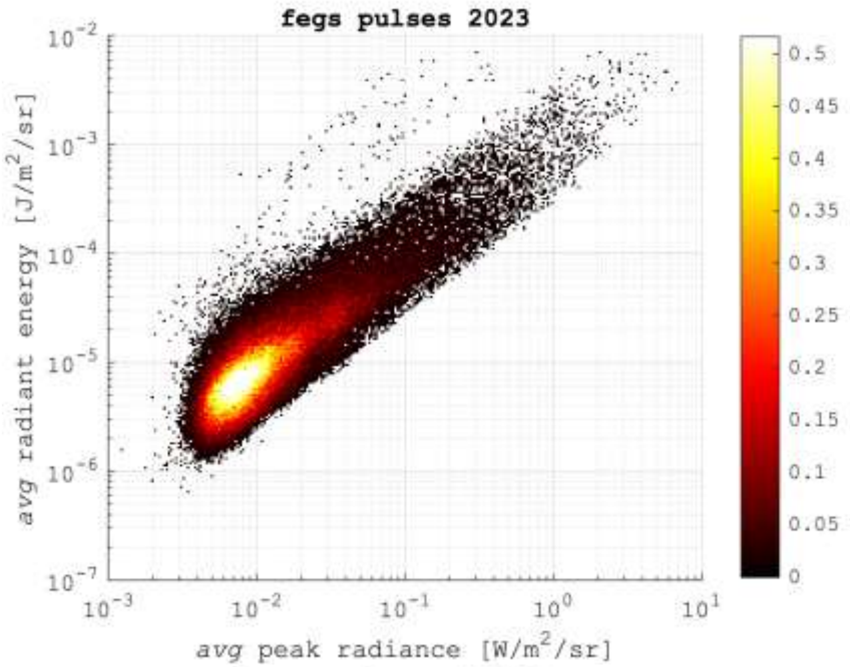
Many hundreds of glow overpasses

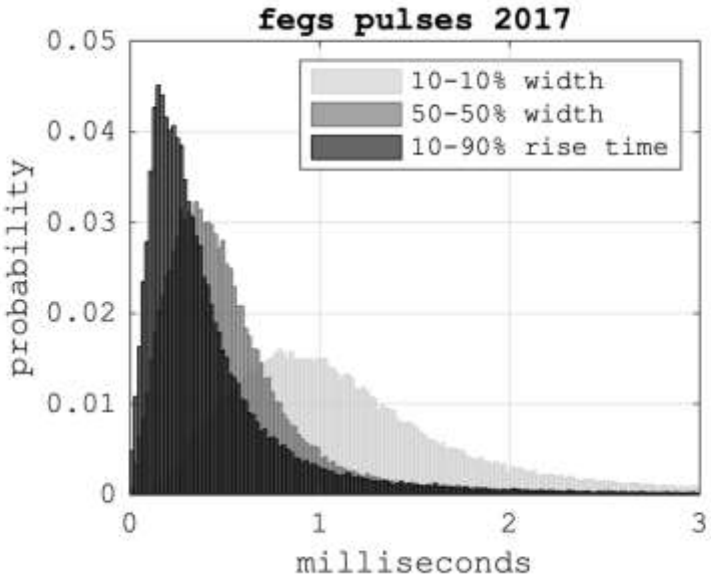
New phenomenology previously unseen

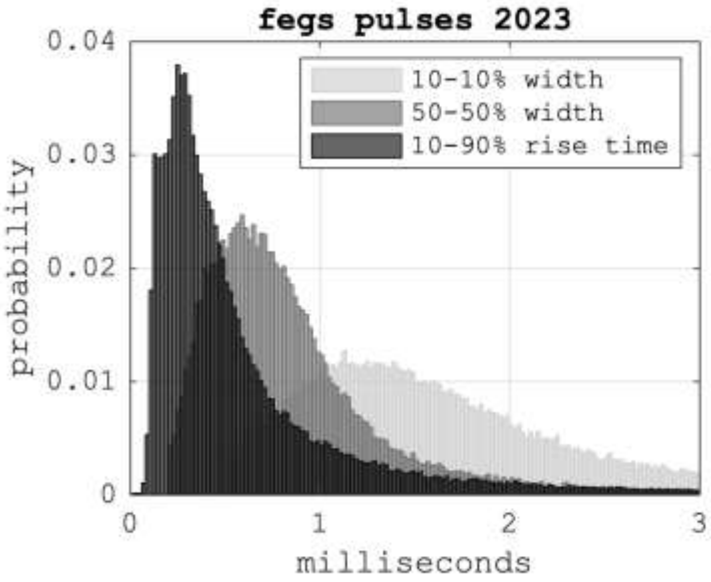
# ALOFT campaign

July 2023



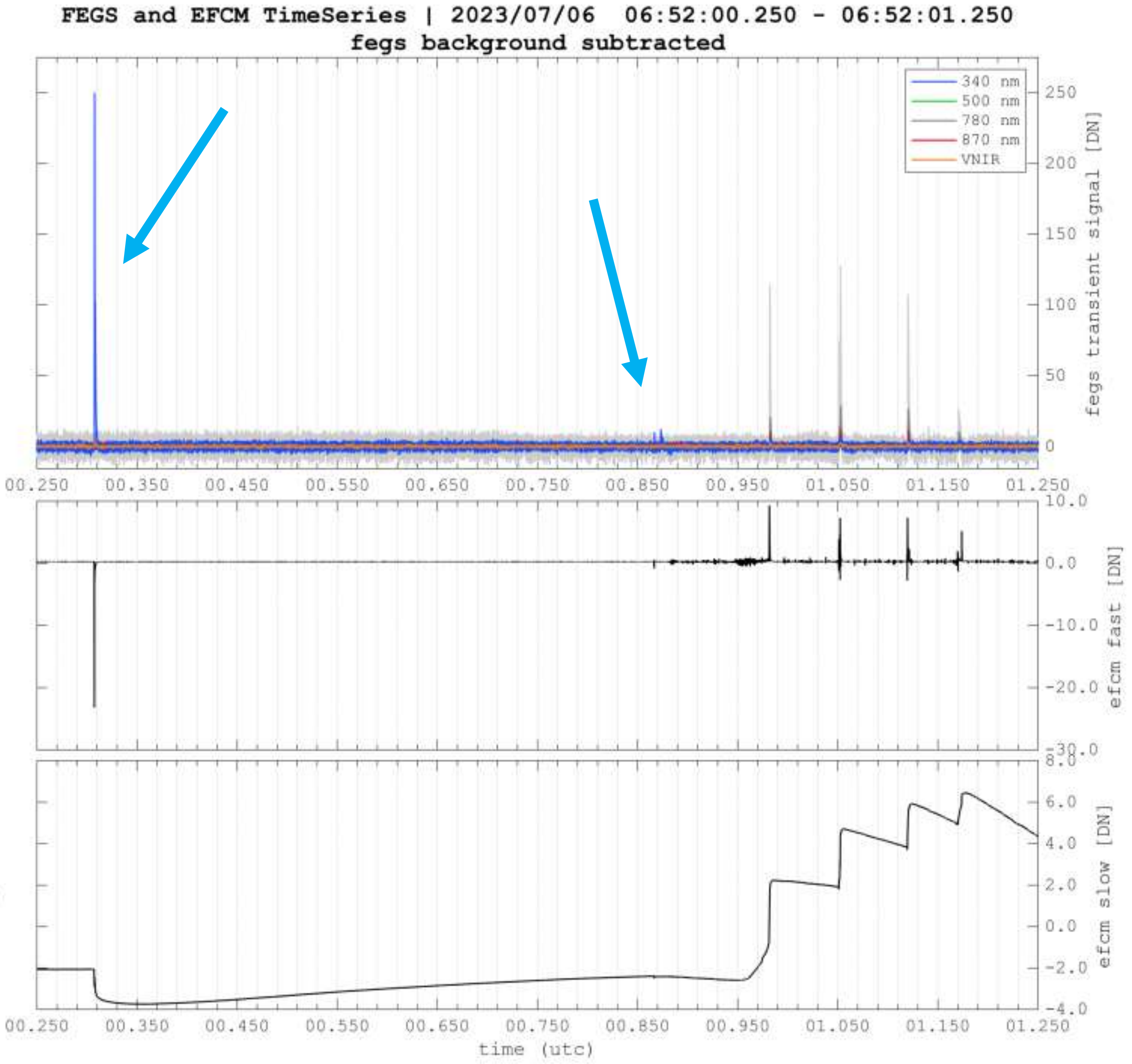

**early look at 2023 measurements…**

- Peak radiance & pulse energy tends to be larger in 2023 (~3x 2017)
- Many more high energy outliers in 2023
- Corresponding wider pulse widths in 2023
- Still investigating why…
  - Calibration differences?
  - Meteorological differences between tropical and mid-latitude convection?
  - Bias toward most intense convective cores in 2023?

Lightning UV emission

Example 1

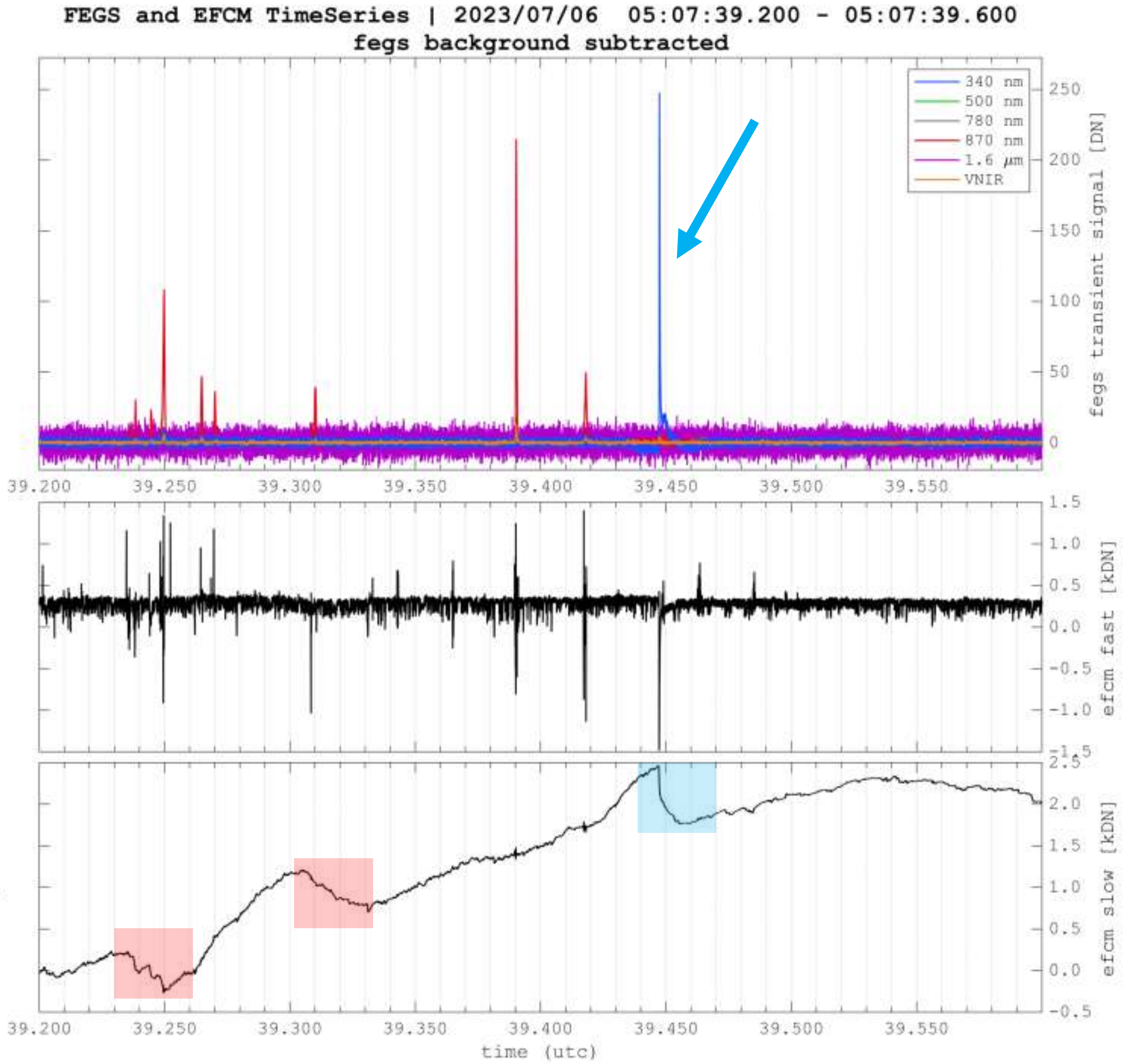
- 1 second sequence of pulses
- Temporally isolated discharge with exclusive UV emission
- Flash initiation observed in UV 100 ms prior to broadband emission
- *Important discharge processes completely invisible to NIR lightning imagers*



Lightning UV emission

Example 2

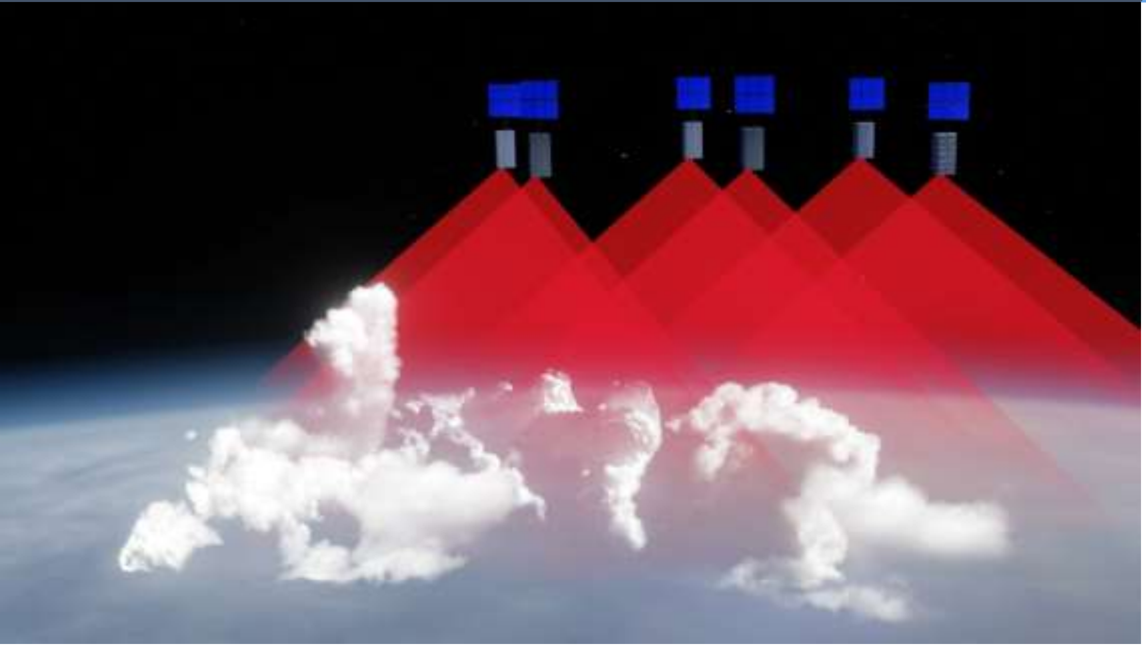
- 400 ms sequence of pulses
- One pulse exclusive 337 nm emission & opposite polarity
- *Electrostatic field-change producing UV emission comparable to broadband processes*



# Cube-Spark Mission

# CLIDE

## CubeSat Lightning Imaging and Detection Experiment

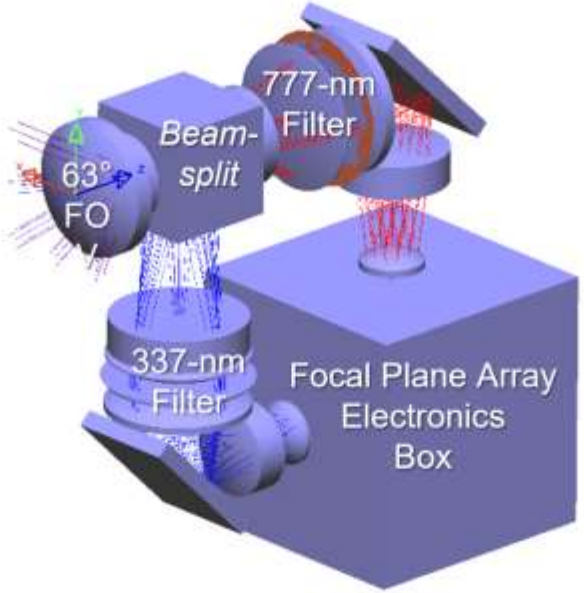


- **Global 3D mapping of thunderstorm charge structure**
- 6 satellite – formation flight
- Combined VHF + optical lightning detection

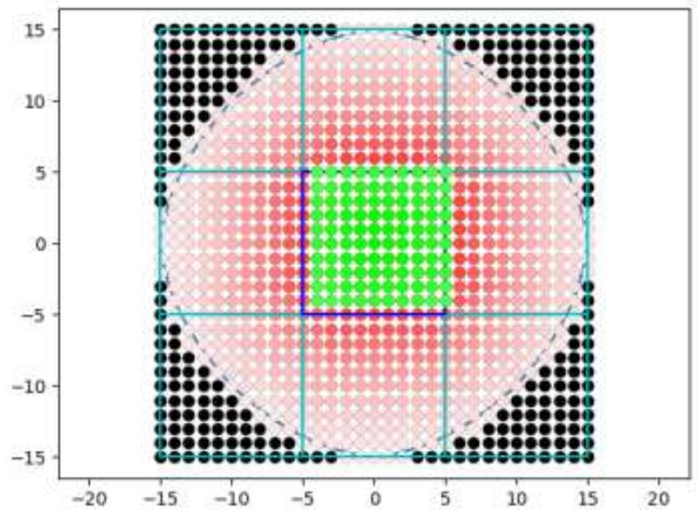
- VHF antenna: Los Alamos National Labs
- Optical Sensor: Marshall Space Flight Center

- **CMOS event detector**
- Bi-spectral (337 + 777 nm)

- SNR in UV channel is significant challenge




CLIDE bi-spectral telescope concept




non-uniform source SNR modelling

**Primary Science Questions Moving Forward:**

1. How do FEGS NIR observations differ between 2017 and 2023? And why?
    - calibration
    - storm characteristics

2. What do ALOFT observations tell us about CLIDE performance requirements?
    - combine with ASIM analysis
    - ISS-LIS, GLM comparison

3. What new information is offered by 2023 spectral channels?
    - process discrimination
    - cloud scattering
    - combine with EFCM, VLF, interferometer

4. How do FEGS optical measurements correlate to thunderstorm micro-physics?
    - aircraft microwave + radar
    - ROSES - WADFA analysis


# Thanks!

# Fly’s Eye GLM Simulator

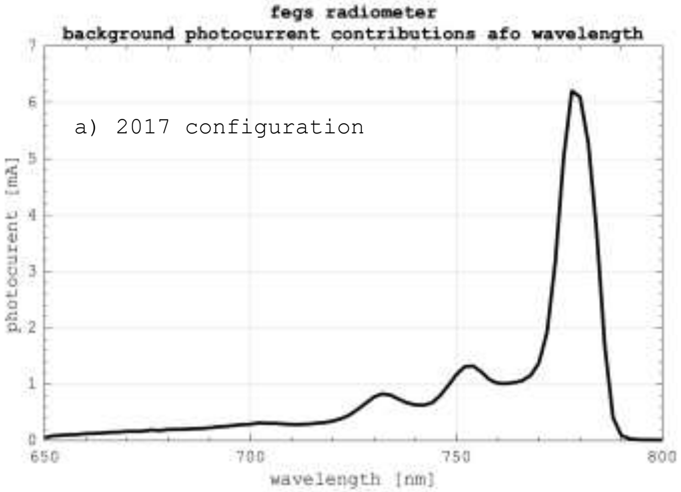
*Improvements in 2023*

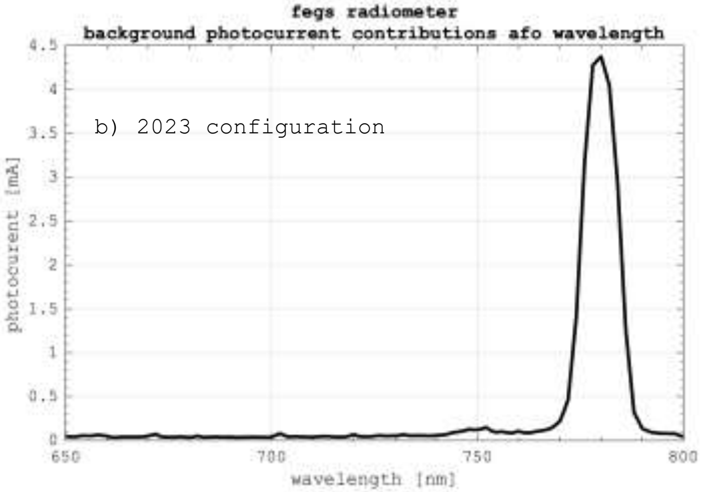
- Significant out-of-band contamination in 2017
- Mostly affected background cloud-top radiance reports
  - Added rejection filter
  - Flat black surface treatment

- Enabled nighttime observations
- Optimized dynamic range

- Version 3-beta pulse detection software

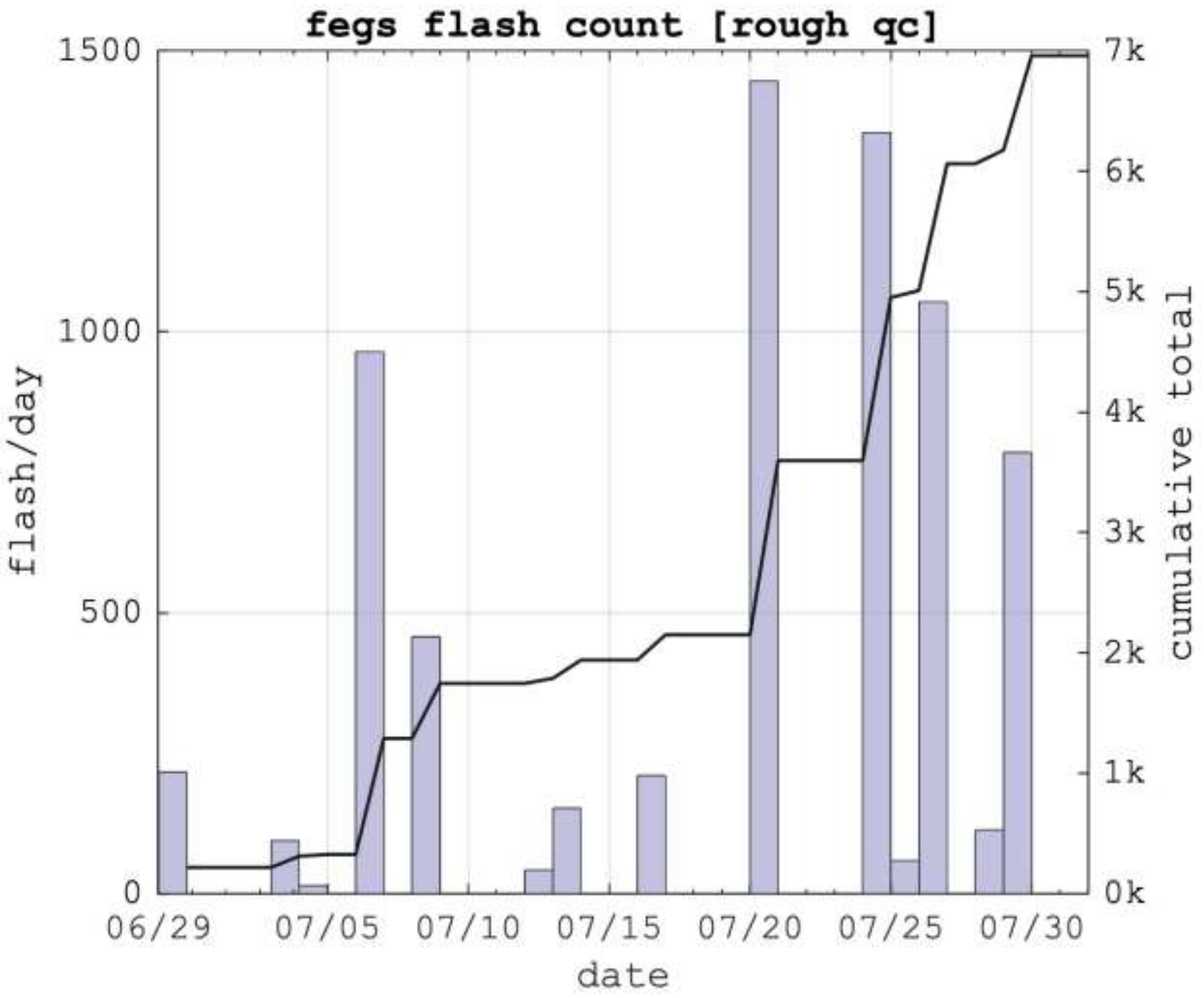
| 2017 | | 2023 | |
|---|---|---|---|
| **CWL (nm)** | **species** | **CWL (nm)** | **species** |
| 340 | N2 | 340 | N2 |
| 400 | NII | 400 | NII |
| 500 | NII | 500 | NII |
| 660 | H | 660 | H |
| 675 | N2 | 675 | N2 |
| 780 | OI | 780 | OI |
| | | 870 | NI |
| | | 1600 | multiple |
| 400-1100 | wideband | 400-1100 | wideband |

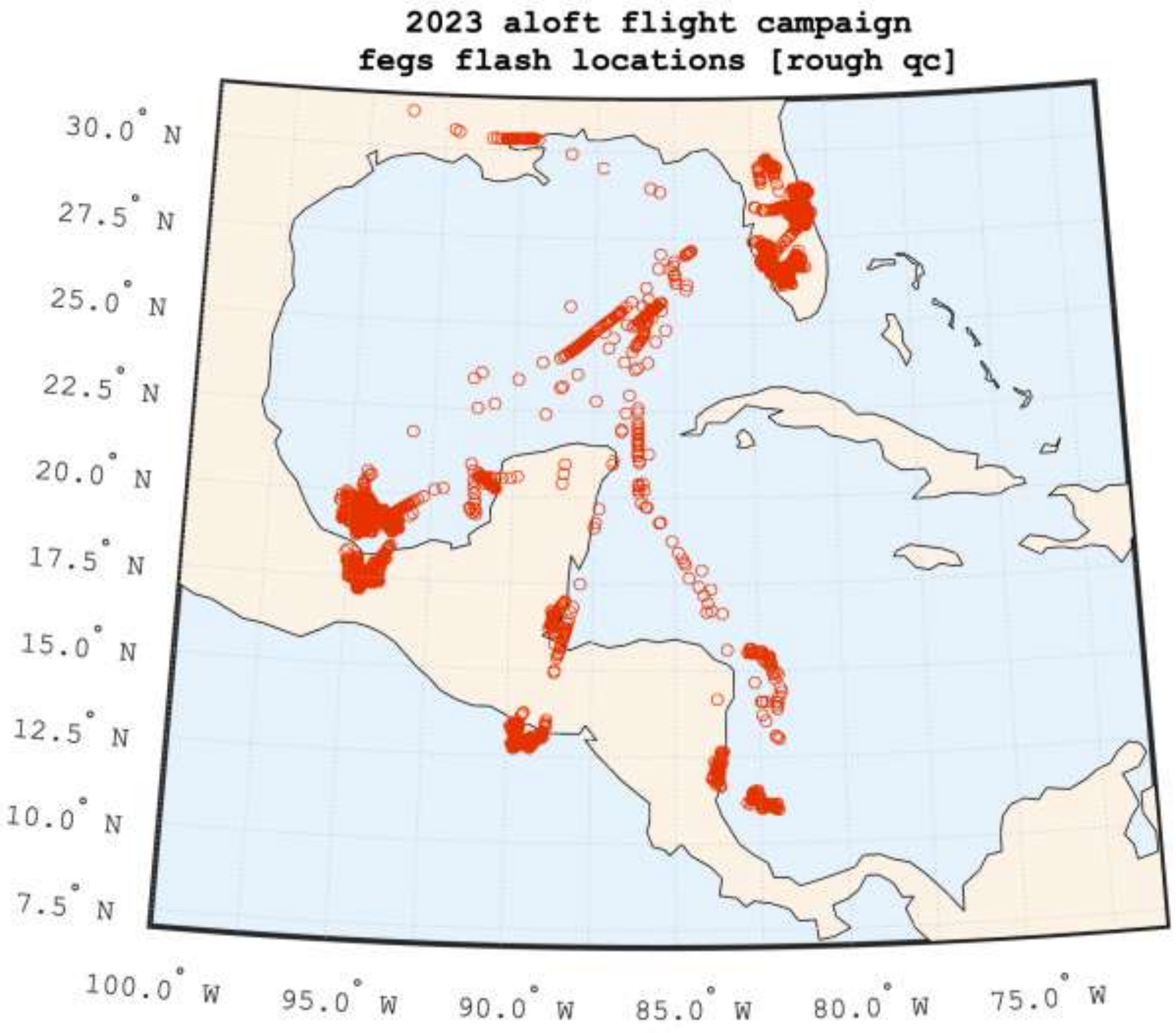



# ALOFT campaign

July 2023



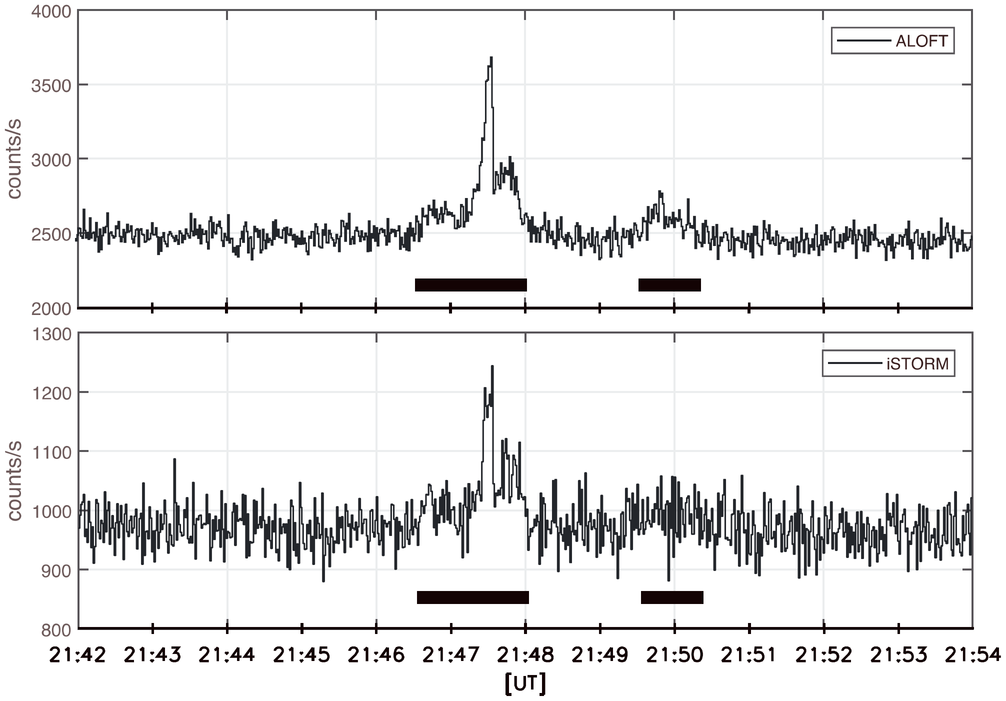



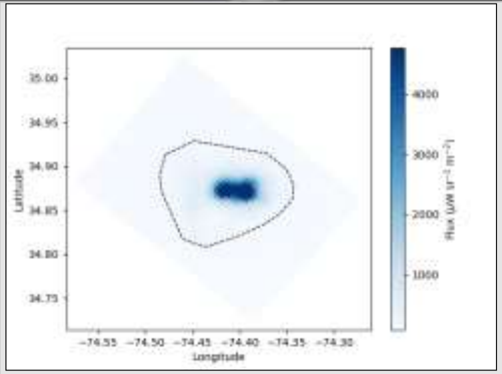
## Single gamma-ray glow detected over Colorado in 2017

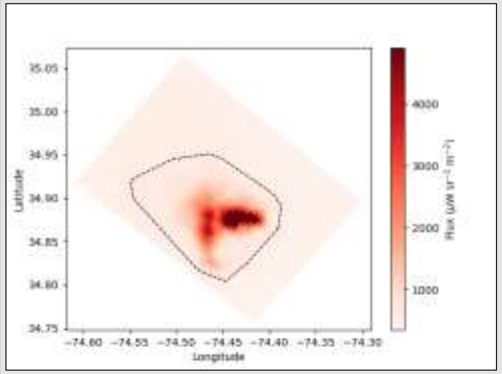
# JGR Atmospheres

### Gamma Ray Glow Observations at 20-km Altitude

N. Østgaard[1], H. J. Christian[2], J. E. Grove[3], D. Sarria[1], A. Mezentsev[1], P. Kochkin[1], N. Lehtinen[1], M. Quick[4], S. Al-Nussirat[5], E. Wulf[3], G. Genov[1], K. Ullaland[1], M. Marisaldi[1], S. Yang[1], and R. J. Blakeslee[4]




## Highly successful Atmospheric Space Interactions Monitor (ASIM) mission on ISS.
## *Launched 2018.*

- **MMIA** (Modular Multispectral Imaging Array)
  - **Imagers**
    - **337 nm**
    - 777 nm
  - **photometers**
    - 180-230 nm
    - 337 nm
    - 777 nm

- **MXGS** (modular x-ray and gamma-ray sensor)
  - low energy detector
    - 15 kEV 400 keV
    - Pixelated + masked
  - High energy detector
    - 200 keV to 40 MeV